



## Frequency control in power systems with large scale wind power

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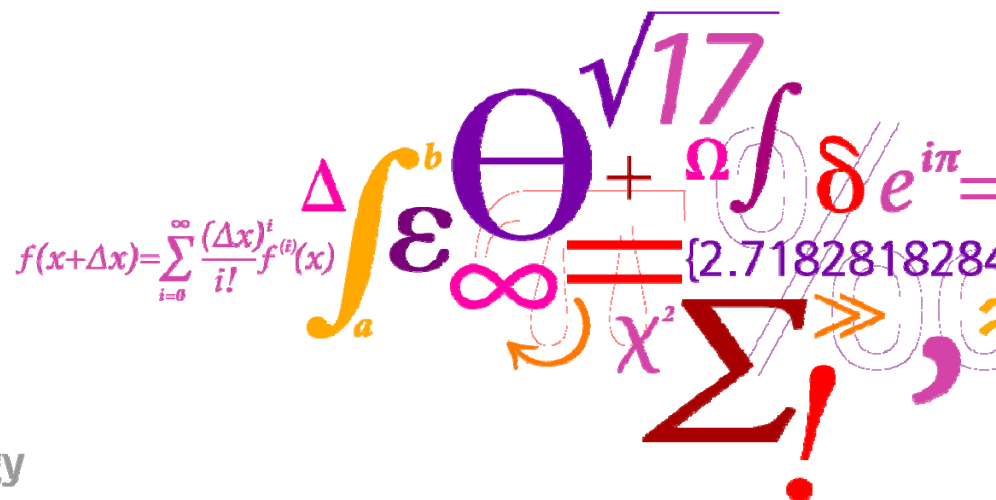
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# Frequency control in power systems with large scale wind power

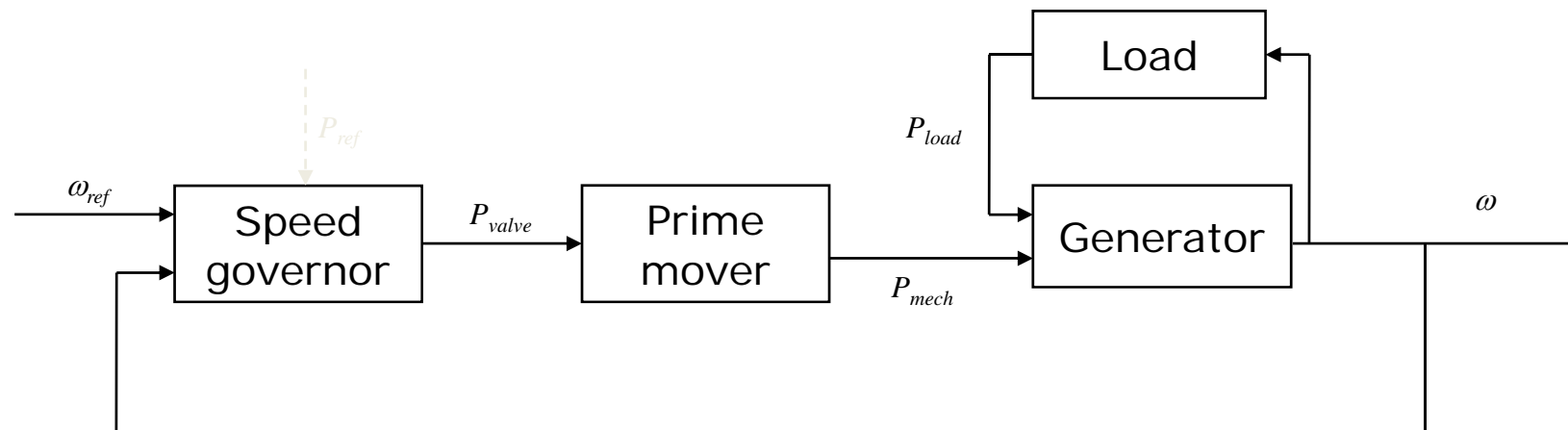
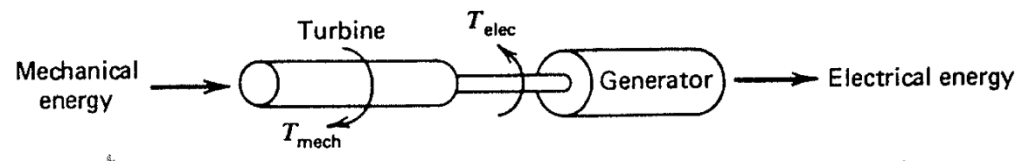
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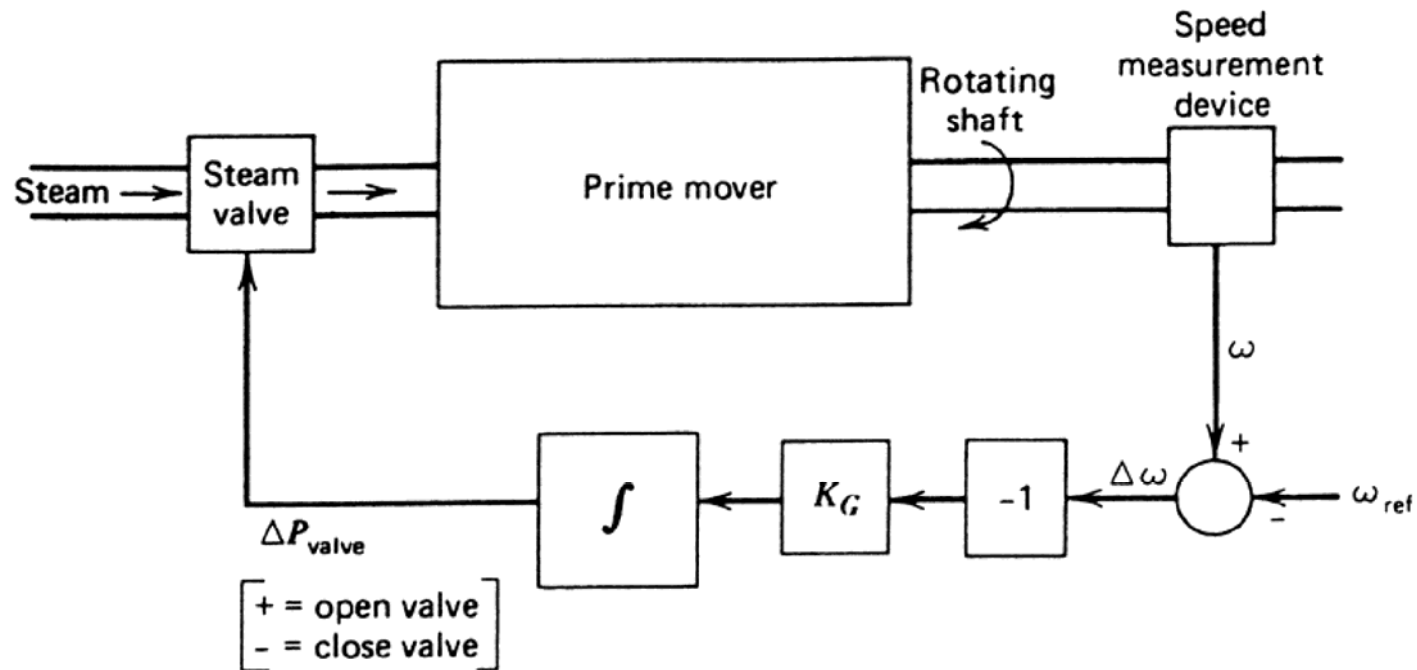
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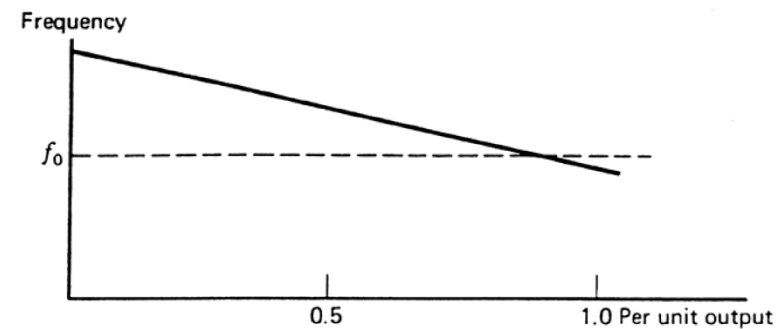
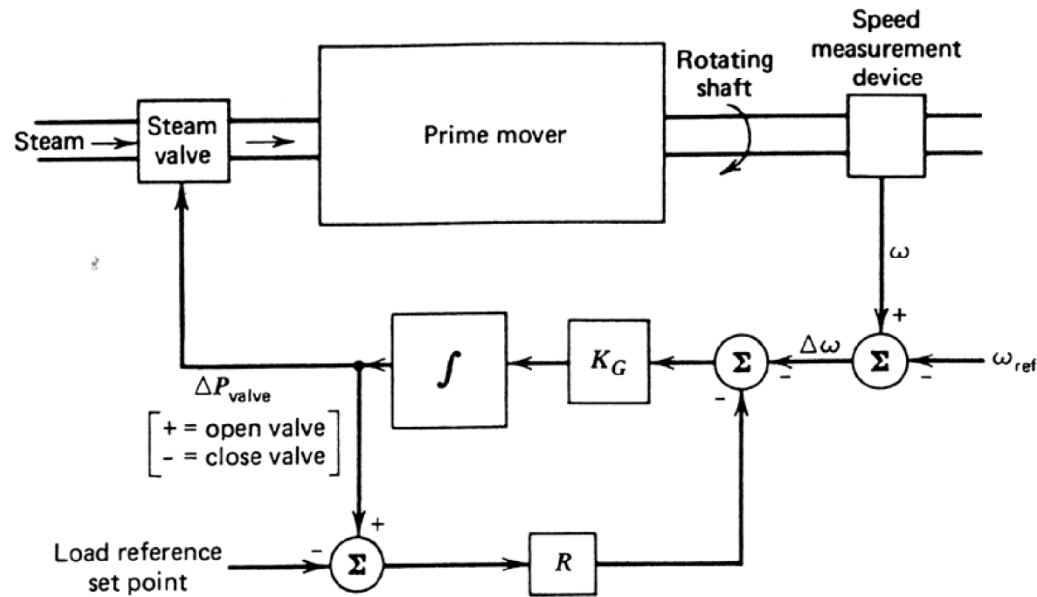
# Frequency control of power systems – text book



# Isochronous governor – single generator



# Speed droop governor – multiple generators



# Frequency control example - Nordel

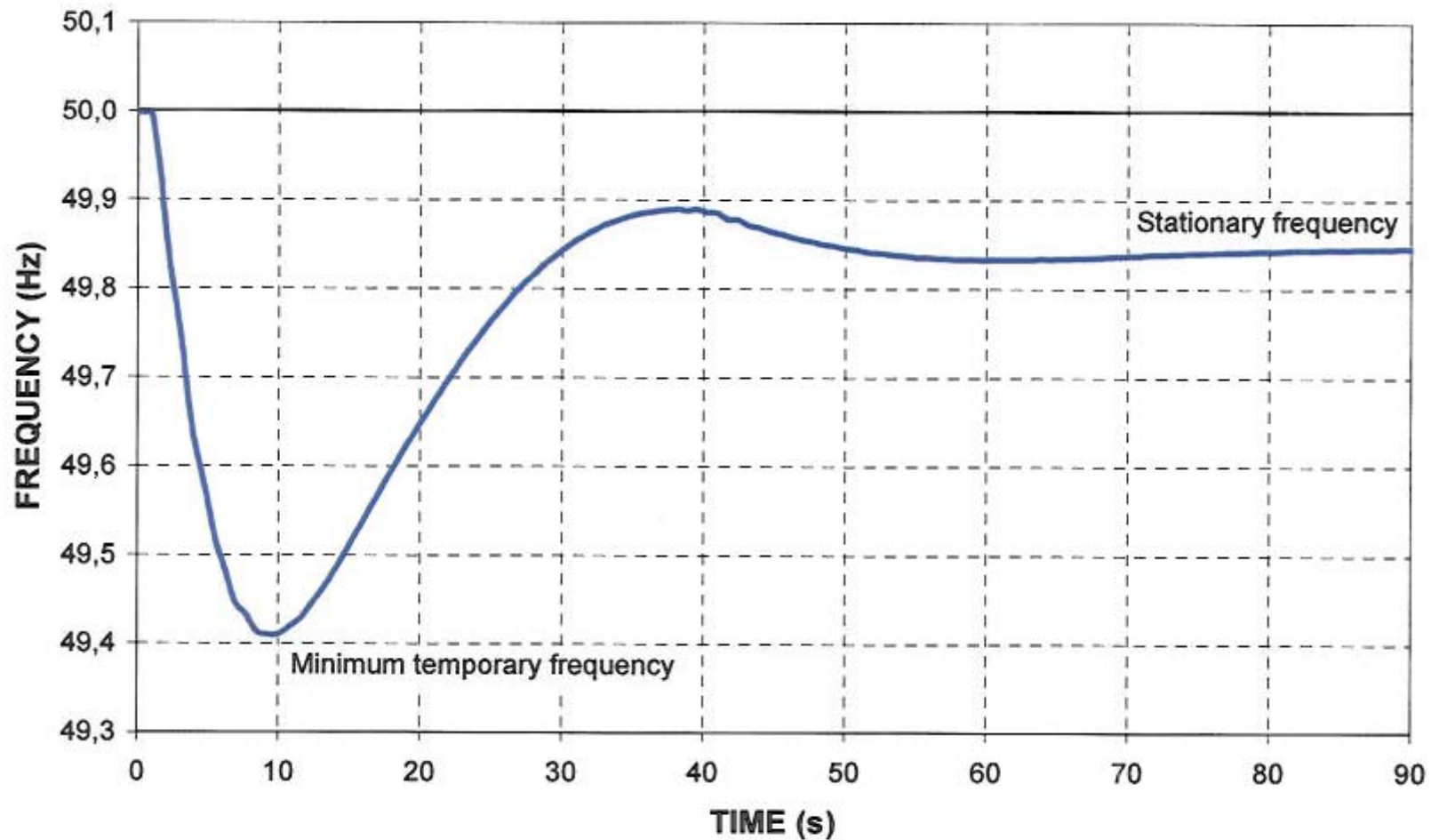
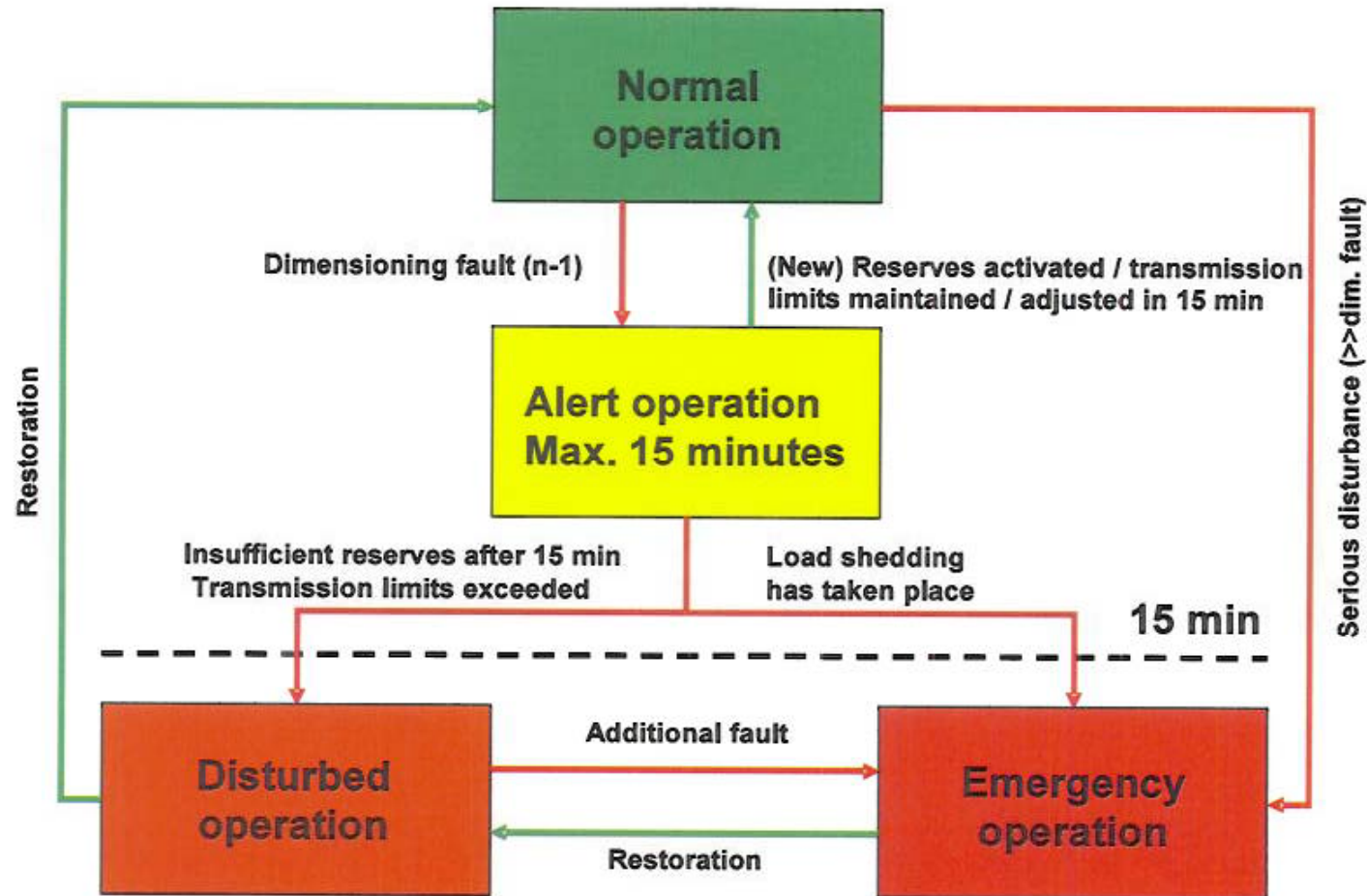


Figure 6 *Development in frequency in Nordel following production outage*

# Why frequency control - Nordel



*Figure 1 Operational states (network collapse is not specified in the figure).*

# Frequency controlled actions

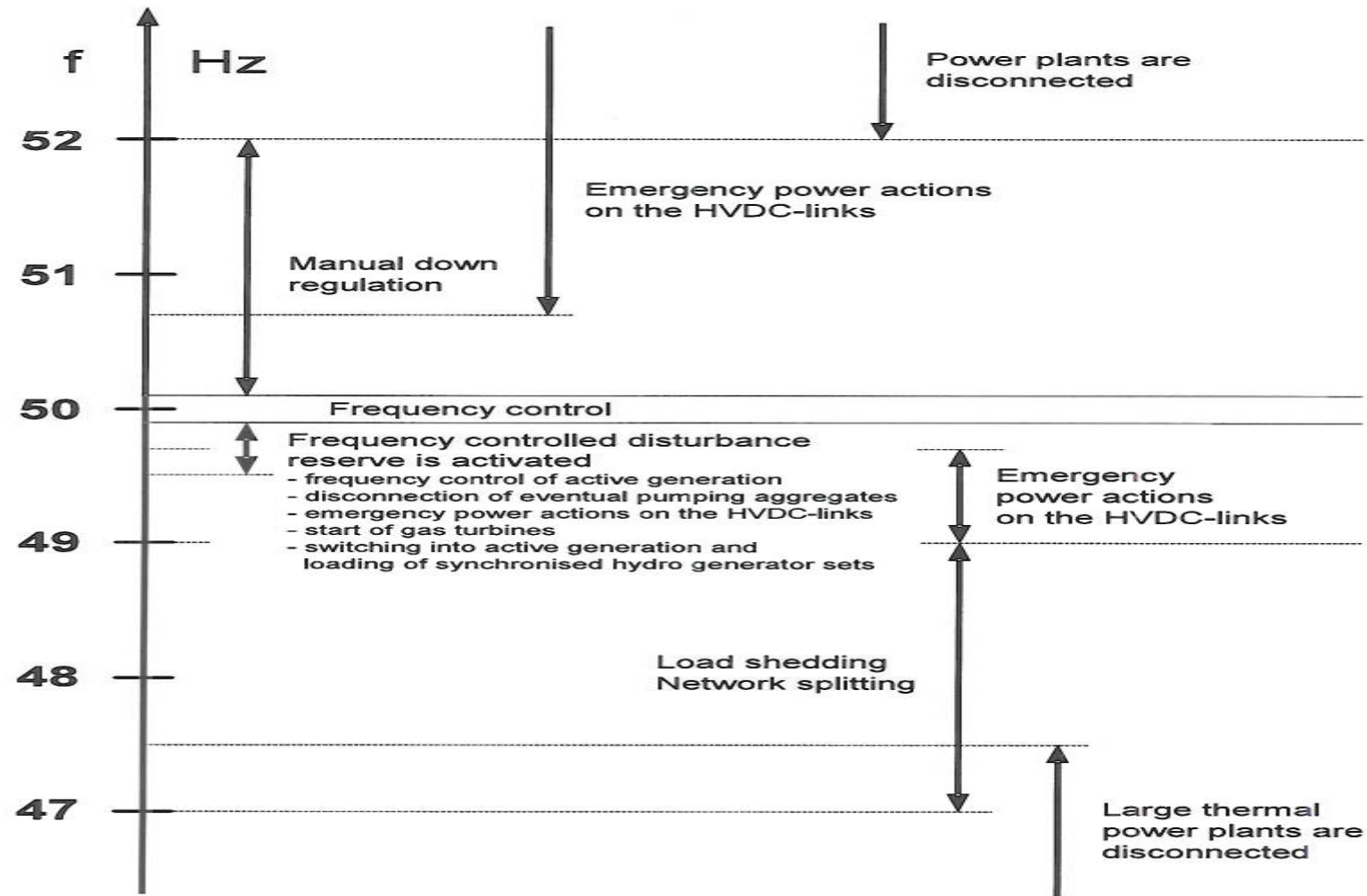
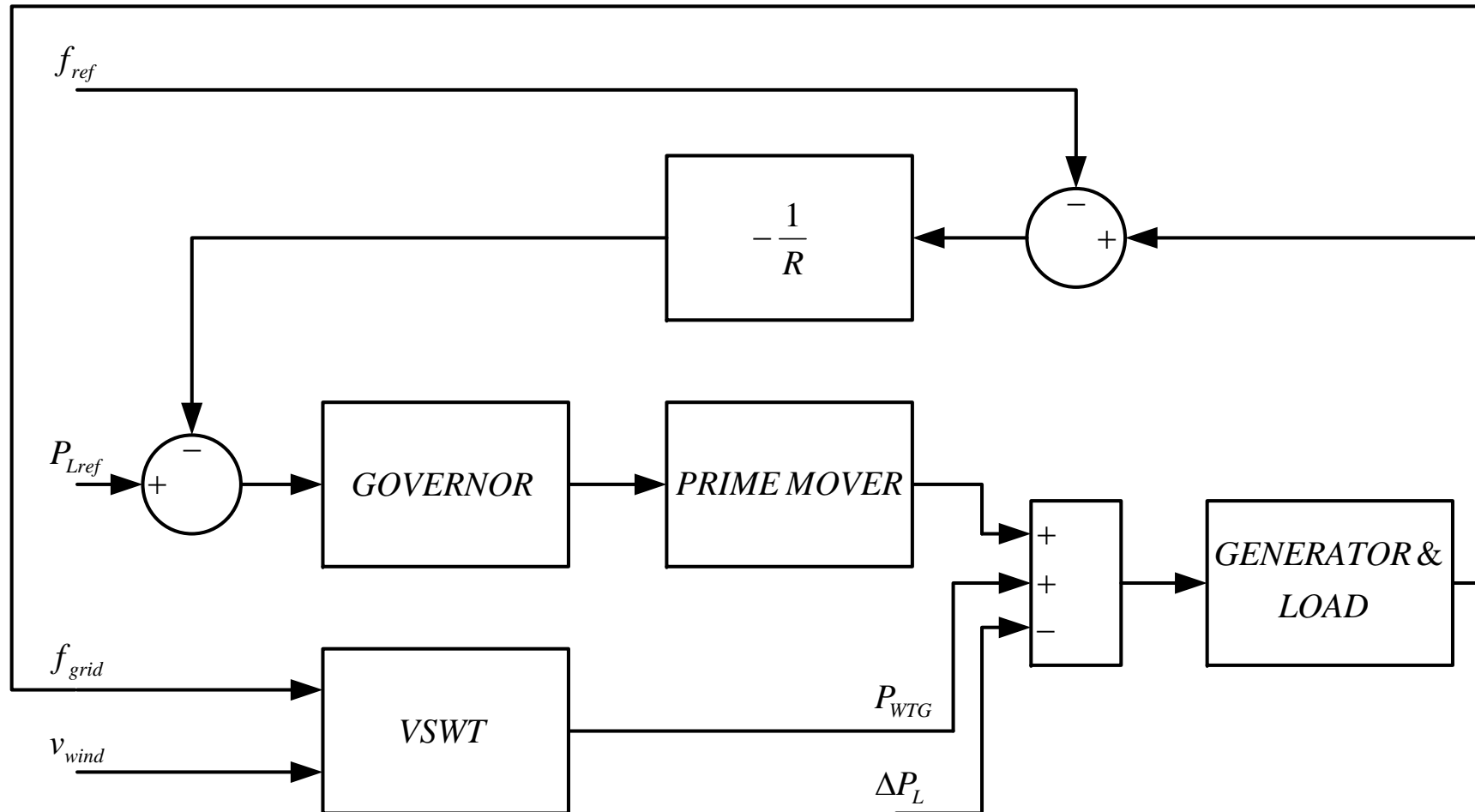


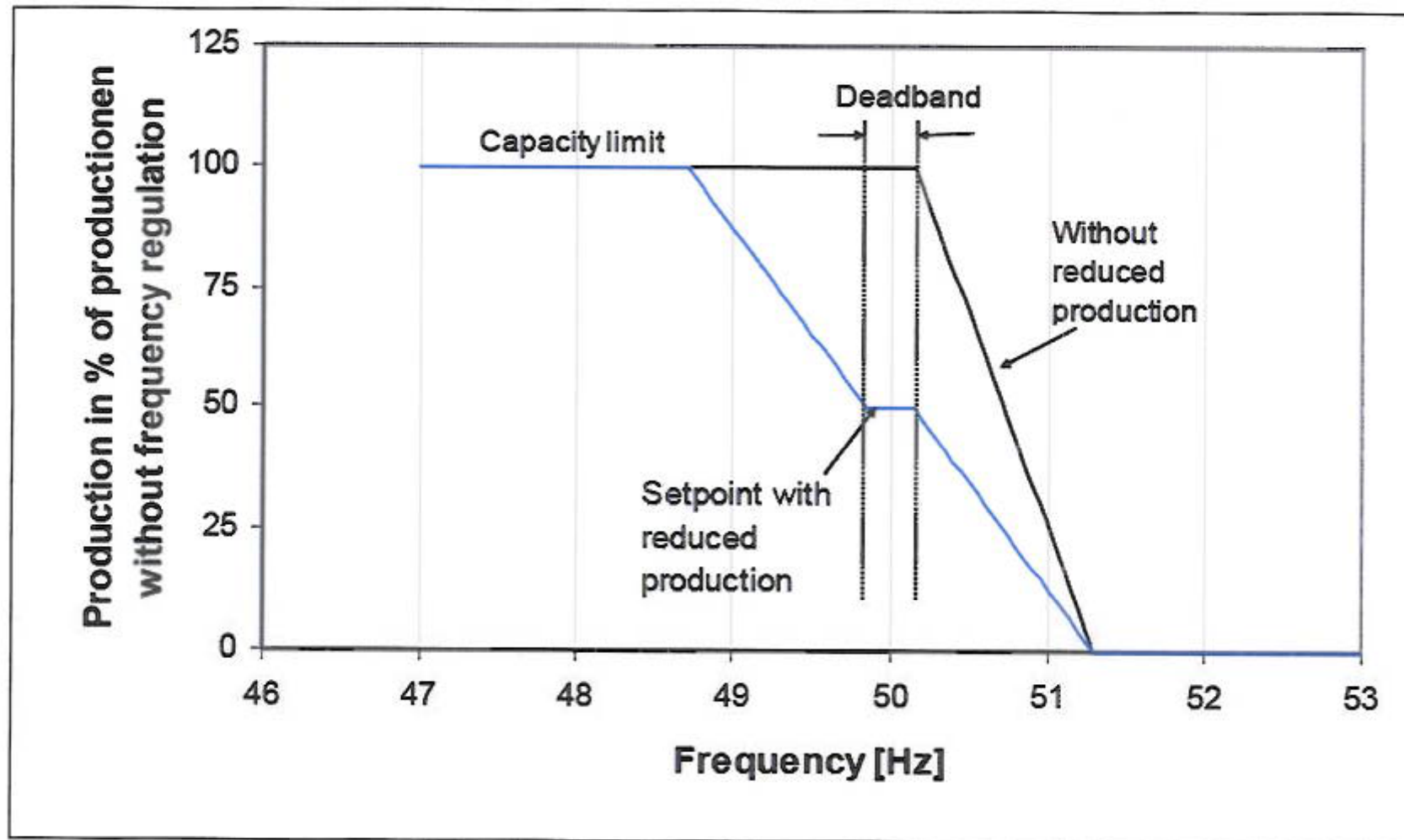
Figure 1 Frequency controlled actions in the Nordel-system



# Frequency control model with wind power



# Danish grid code for wind turbines

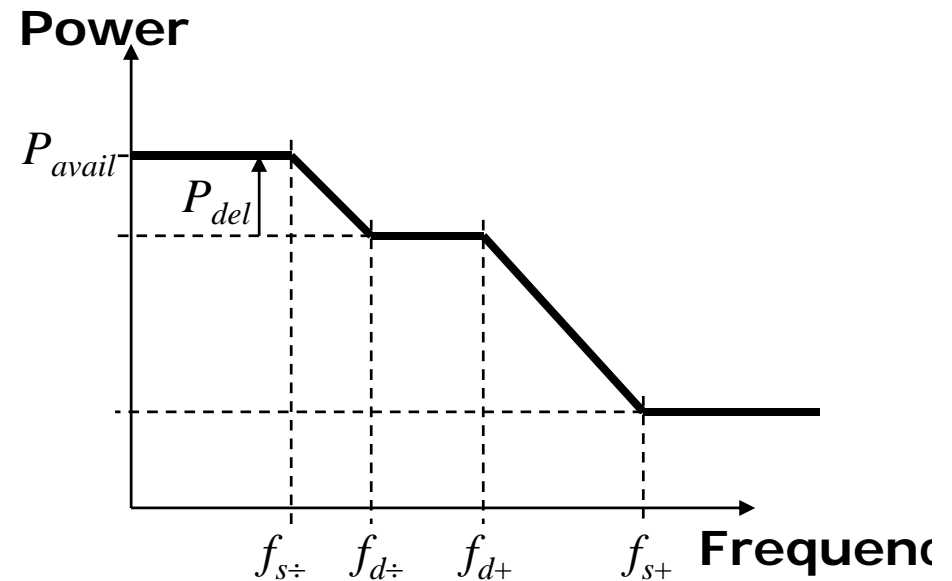
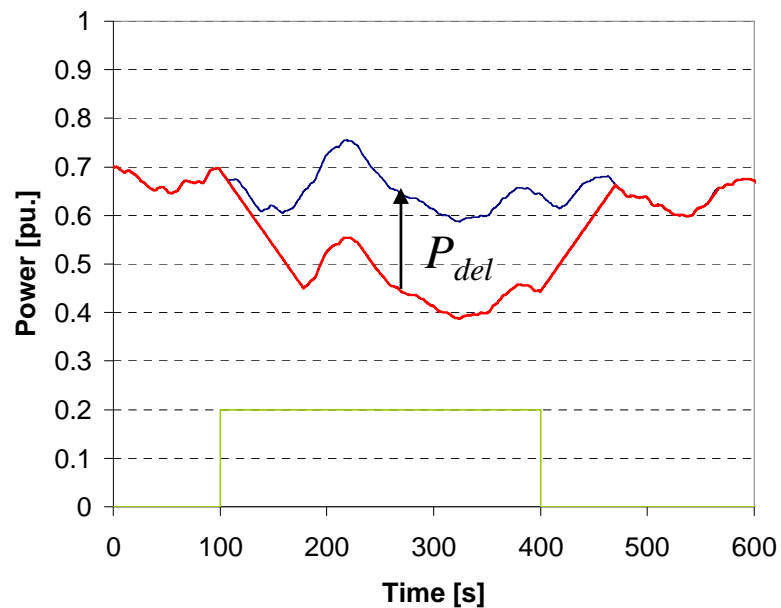


*Figure 1 Frequency control based on the default values in Table 1.*

# Delta control – Danish grid code

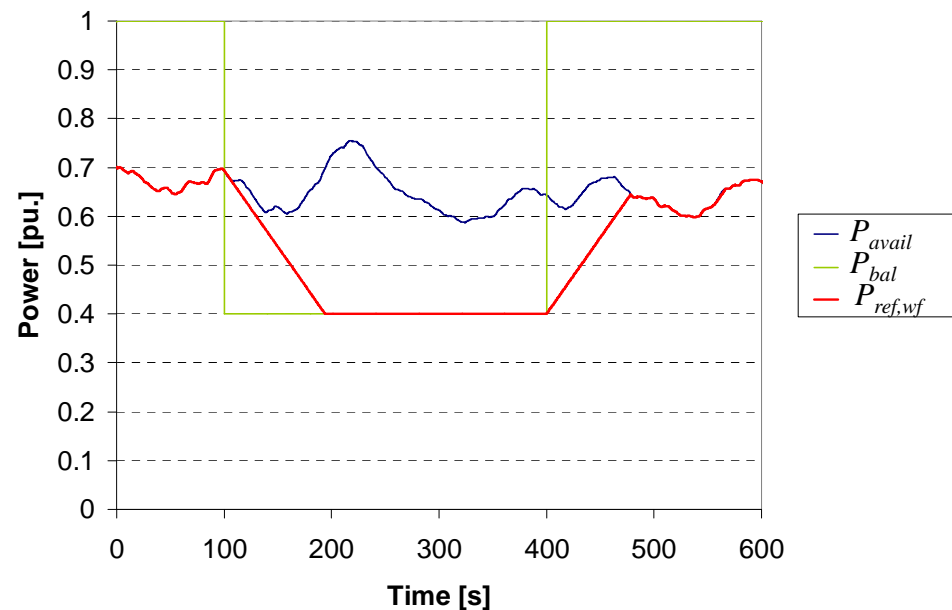


- Delta control provides fixed reserve
- Delta control already implemented in Horns Rev and Nysted
- Reserve can be utilised in frequency control (droop and deadband)



# Balance control – Danish grid code

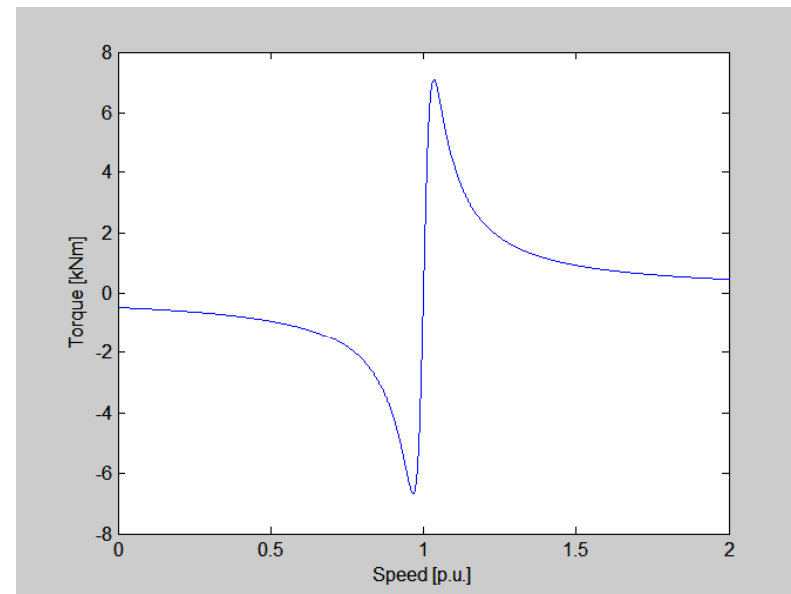
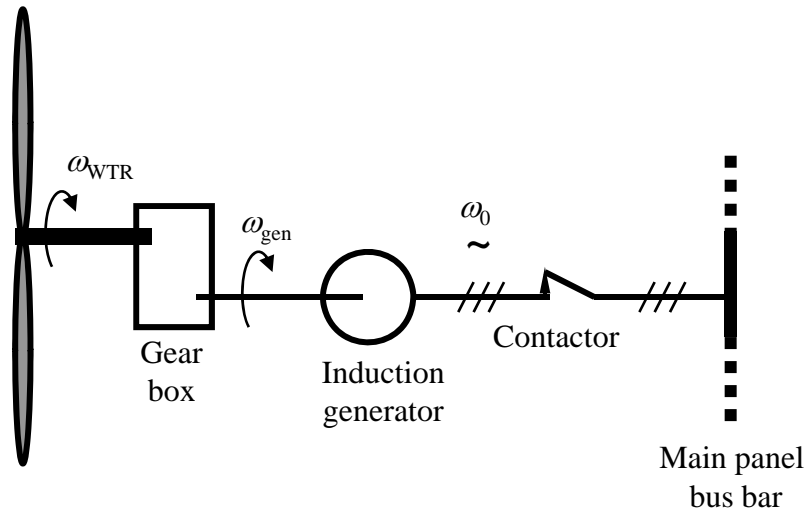
- Balance control provides
- Balance control already implemented in Horns Rev and Nysted



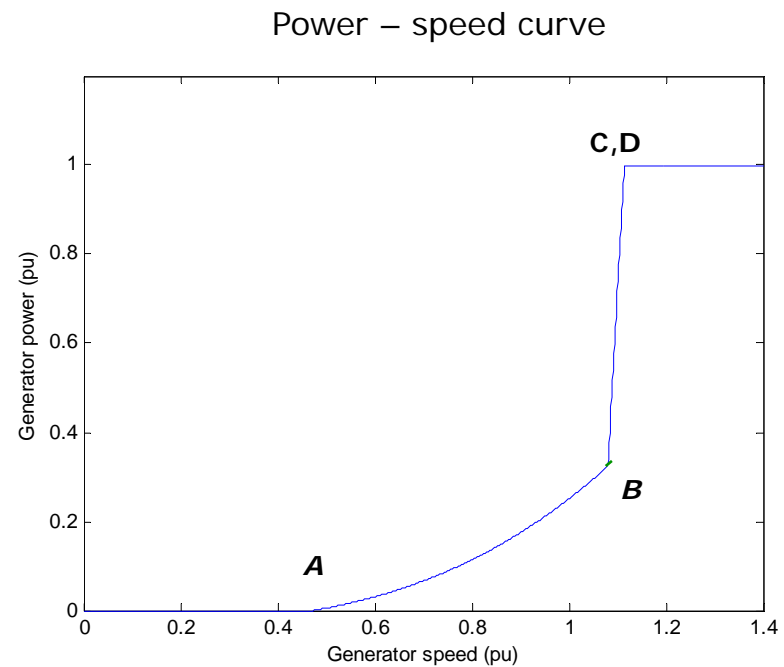
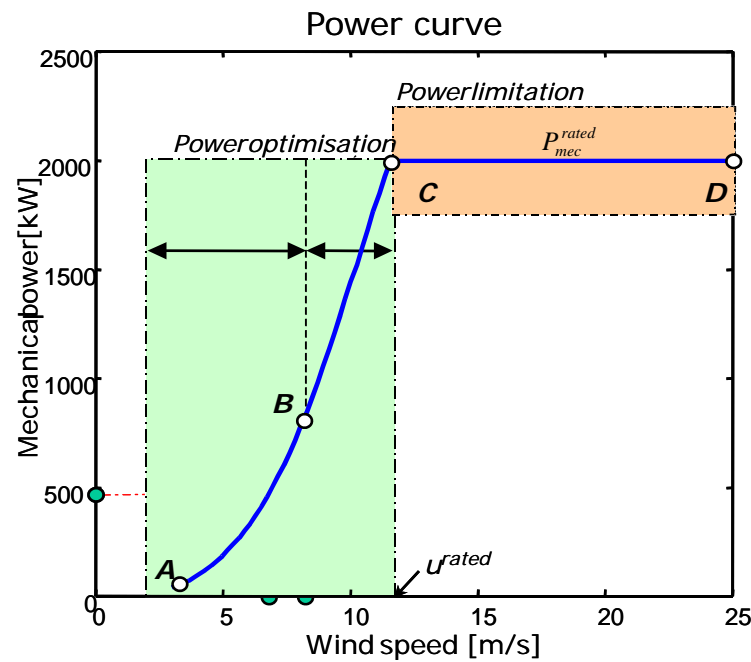
- 45002 Modelling and analysis of sustainable energy systems – 3 final projects on frequency control (1 week work load)
- Impact of wind power fluctuations on frequency control
  - The purpose was to study the impact of wind power fluctuations on the primary frequency control in small island power systems.
- Wind power frequency droop control
  - The purpose was to develop and implement a frequency droop control for a fixed speed wind turbine and show how this control feature can contribute to the power system frequency control.
- Variable speed virtual inertia
  - The purpose was to develop and implement a virtual inertia control for a variable speed wind turbine and show how this control feature can contribute to the power system inertia.

# Fixed speed wind turbine

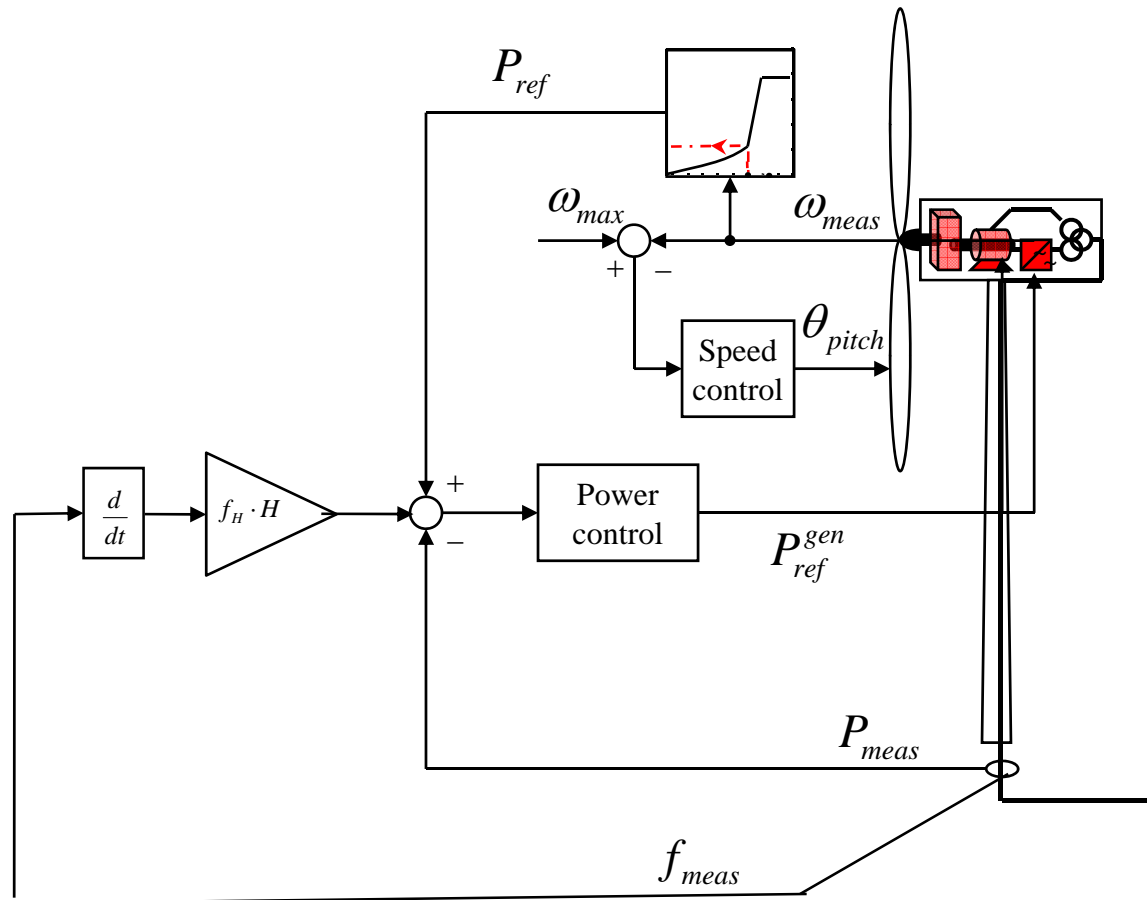
## "passive control" – natural inertia



# Variable speed wind turbine control strategy

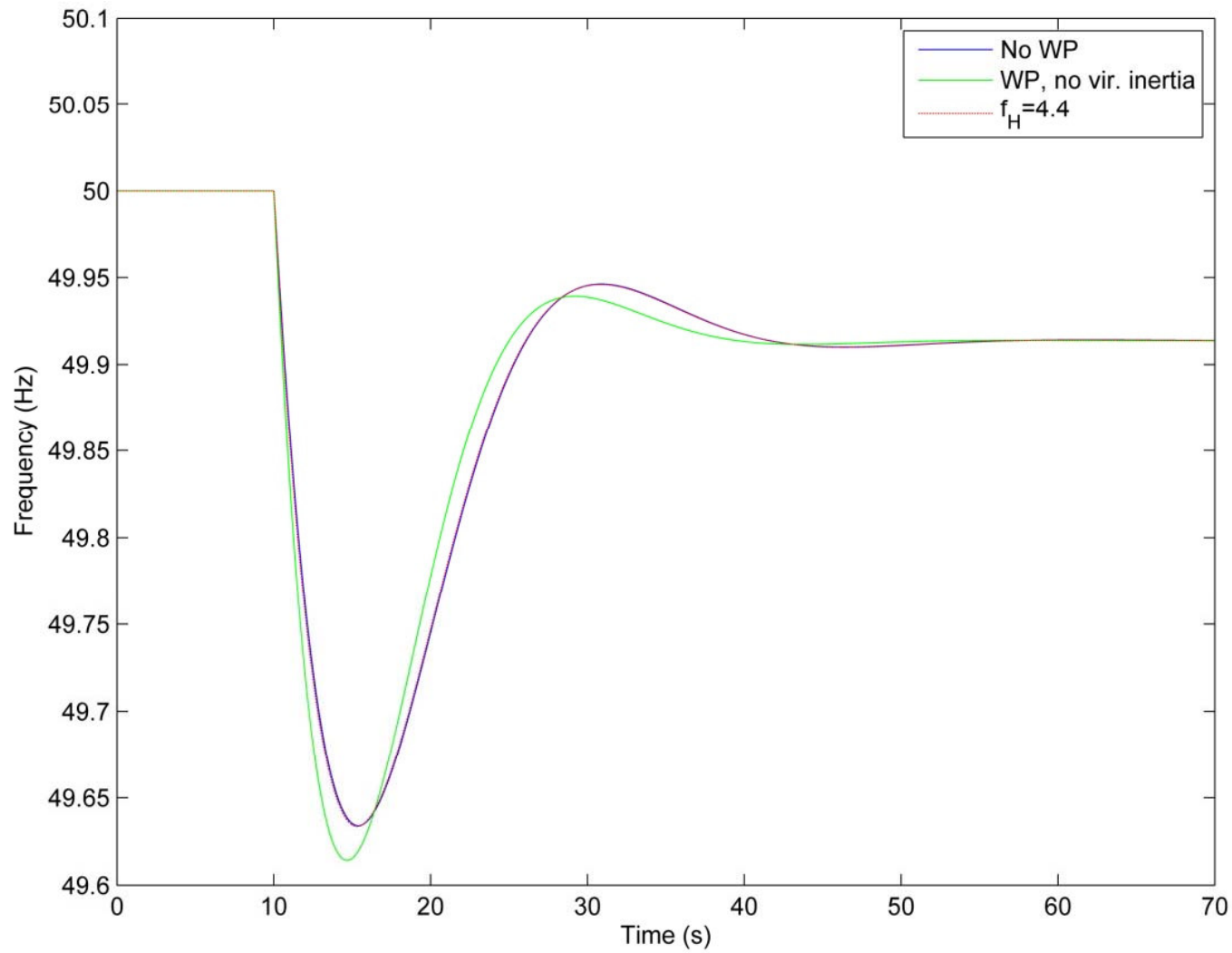


# DFIG power / speed control overview

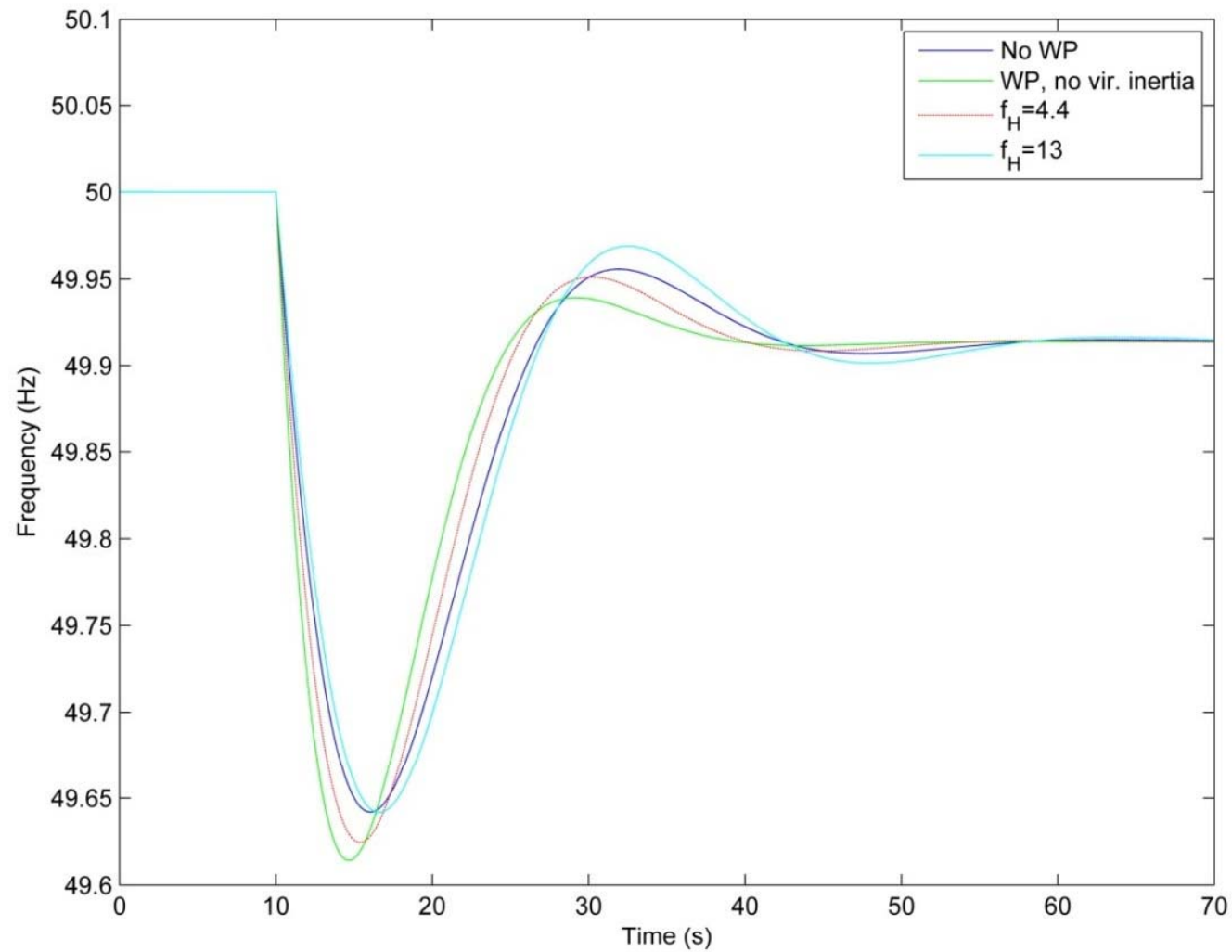




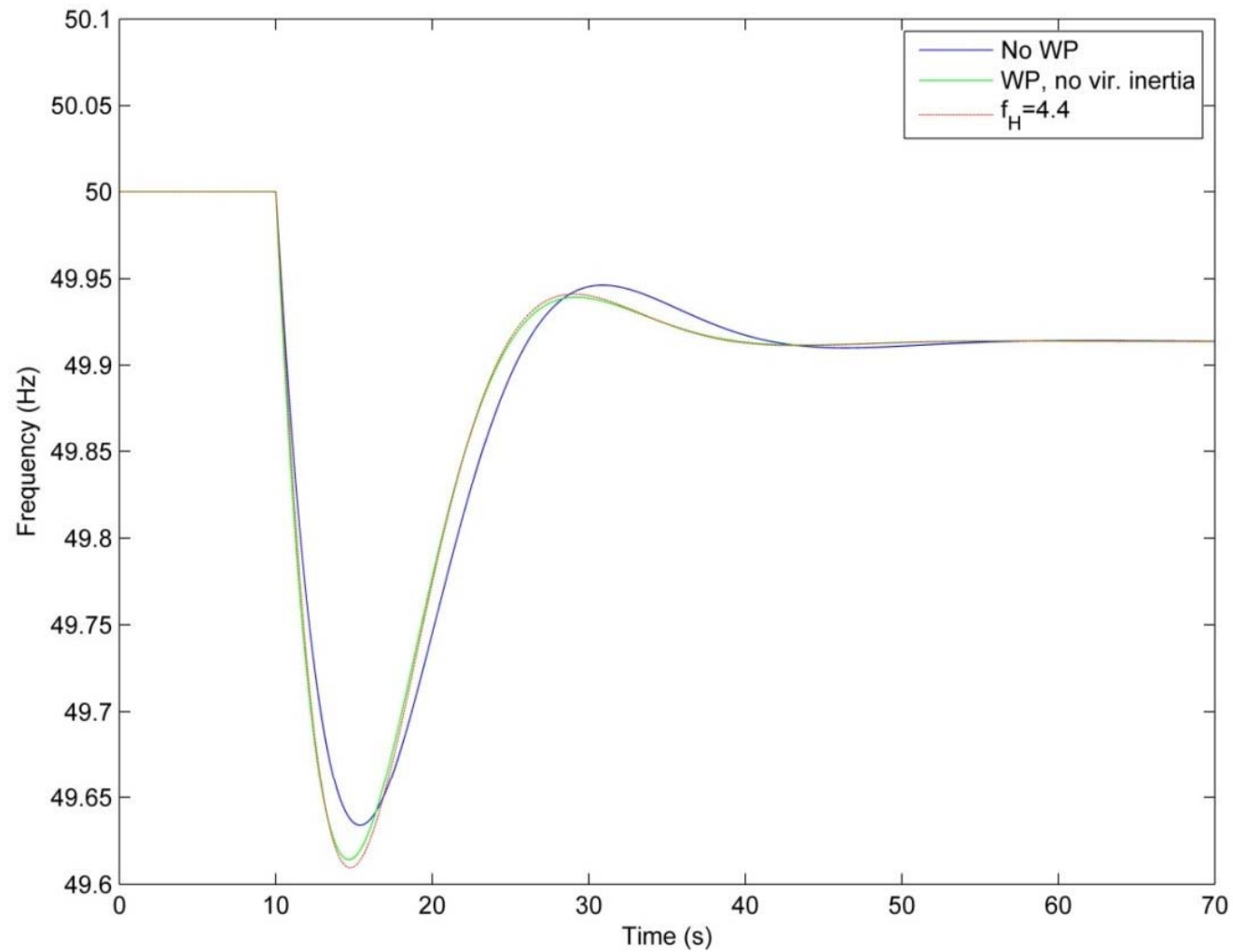
# Virtual inertia control – 16 m/s



# Virtual inertia control – 8 m/s



# Virtual inertia control – 12 m/s



# Conclusions on wind turbines provision of frequency control



- Wind power can contribute to frequency control
  - Inertia
  - Droop (automatic, primary)
  - Regulating power (secondary or tertiary reserves)
- Virtual inertia control can be provided without loss of wind power, positive reserves (droop or secondary) cost significant loss of wind power
- Simple virtual inertia control add-on does not work properly with standard speed – power lookup control algorithm
  - Power limitation region (CD) works perfect
  - Power optimisation – no speed limit region (AB) works partly
  - Power optimisation – speed limited region (BC) works very poorly.
- Alternative control algorithms should be able to solve this problem